ANALYSIS OF KNEE BONE AND CARTILAGE SEGMENTATION IN ORTHOPEDIC KNEE MR IMAGES

A SYNOPSIS

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1.INTRODUCTION

Knee joint is a very intricate and interconnected joint in the body of the persons. This joint contains two articulations. One of them is located between the femur and tibia bone. Another one is located between the patella and femur. This joint is shaped by the condyles of the femur bone and tibia bone. The inner structure of knee joint contains synovial cavity containing synovial fluid, articular cartilage, meniscus region (semi-lunar cartilages), cruciate ligaments, and burse.

Articular Cartilage has a skinny coating of ultra slippery hyaline material, covering the patella, tibia and femur bones. The growth of osteoarthritis (OA) is determined by the change occurred in the cartilage thickness. Osteoarthritis is a widely known disease caused in the knee joint and presents generally in the aged persons. The reason for this disease is the erosion of cartilage, occurred due to the incessant wear and tear actions. Then the cartilage damages gradually and fades away totally. In this disease, synovial fluid loses its ability to give essential lubrication and hence pain, inflammation and reduced movement of the joint will occur. In this period, the bones scratch each other and new tiny bones known as spurs start to grow. Hence the action of cartilage as a shock-absorber is limited. Thus the stress on joint produces a severe effect. To provide valuable treatment to inhibit or reduce the growth of OA, it is essential to analyze the robust biomarkers of the roots of the disease.

The osteoarthritis initiative (OAI) is an organization sponsored by many public and private health related organizations. The main aim of OAI is to detect the biomarkers responsible for the cause and development of OA at the knee joint. OAI study has 4796 men and women whose age falls in the range of 45 to 79 years. It contains about fifty thousand images of left and right knees. The authors analyzed the effect of OA in India. They reported that about 50.2% of people with the age of 65 to 74 years and 97.7% of people having the 84 years and above, are affected by OA disease. The occurrence of OA developed more if body mass index (BMI) is more. Among the older people, the percentage varied based on the BMI value. It was 51.36% for the people with a BMI below 25 and 100% for the people with a BMI above 40.

In order to examine the cartilage damage occurred because of OA, the thickness of cartilage must be measured. Knee joint defects are diagnosed by using Magnetic Resonance Images (MRI). MRI scan is used to examine in-vivo and in-vitro structures of the human body since it is non-invasive and has high resolution soft tissue contrast. The knee joint images from MRI scan can be obtained in three different planes. They are sagittal, coronal and axial planes. Images in sagittal planes give a enhanced representation of cartilage when comparing with the other two planes. From the various time series of MR images, the physicians detect femur, tibia and cartilage of knee bone and examine the impact of OA.

Normally the human body contains about 70 - 80% water. While capturing the image of the knee from the MRI scanner, the large magnetic field of the MRI scanner makes the hydrogen of water molecules to come in parallel with the direction of the magnetic field. A radio transmitter emits an electromagnetic field with different intensities from 1-10T according to the nature of the scanner. After that the photons with resonance frequency are absorbed by the aligned protons and flip. Hence hydrogen emits the energy difference as photons on removal of the field. The MRI scanner detects these photons as radio waves.

The MRI images must be applied with suitable image processing methods for quantization. Presently, many MRI markers are used to detect OA disease; they are cartilage thickness, osteophytes, bone reshape, bone marrow lesions, meniscal lesions, and synovitis. These factors depend on the exact detection of bone surface. Since segmentation technique splits the image into different parts, in medical image processing, it is used to differentiate the abnormal part from the normal part.

In the knee joint MR image, a fully automatic segmentation is used to compute the changes happened in the knee structure and to assess the effect of drugs and other treatments. Different features like image texture, contrast between same tissue, the contrast between slices, and orientation of joint in the image yield different solutions. The changes in knee cartilage can be measure from the morphological measures which are volume, thickness and area. The cartilage must be segmented prior measuring these factors. In segmentation of bones, the major difficulty is the wrong segmentation of fat tissues as the bone

since the intensity of fat tissues is same as that of the bone. Hence an effective segmentation algorithm is necessary to segment the region accurately. Many segmentation techniques have been presented in literatures which are described in the next section. These works have employed active contours, shape models, graph cuts, normalized cuts, and multi-atlas.

In this research, an automatic segmentation technique based on the proximal splitting method is presented and Douglas-Rachford splitting algorithm is employed. The knee joint structures are analyzed and the cartilage region is segmented. Then the quantization of the cartilage region is performed in which several morphological measures are computed. These measures can used to find out the growth of OA and the effects of drugs on OA.

2. LITERATURE REVIEW

Many works related to knee joint segmentation, cartilage thickness measurement, bone segmentation have been presented.

Folkesson et al. [1] presented an automatic segmentation technique using two-step multiclass classification process. The method presented is based on supervised learning. The authors used k-nearest neighbor algorithm as a binary classification technique to detect the cartilage from the background and a multiclass classifier which was a three-class type labels each voxel of the cartilage region with any one class of the three classes. The input images are obtained from a low-field scanner.

Grau et al. [2] presented a modified watershed transformation algorithm which used the previous data. They introduced a non-model-based approach using a multi-surface graph search technique as a semi-automatic technique for cartilage segmentation. Still, these works did not segment the cartilage with the patella and provided lower performance.

Tamez-Pena et al. [3] presented a fully automatic knee joint segmentation technique was presented in which segmented the femoral cartilage and tibial cartilage in a knee joint image obtained from MRI scanner. The authors observed the accuracy of various morphological measurements like femoral trochlea, medial tibia, lateral femur and lateral tibia.

Ringenbach et al. [4] presented the hybrid segmentation technique which used a statistical shape model and a fast-marching algorithm as pre-

segmentation techniques. This method provided better performance by segmenting the femur, tibia, and patella regions. However, it did not fit well for segmenting the cartilage area, since this technique is not good for images with fragile bone borders.

In the work of Dodin et al [5] an automatic segmentation algorithm was applied to 3-D MRI images. Their method segmented the cartilage boundary for the femur and tibia region with the help of a separate segmentation technique. Initially the scan images are sampled in the bone surface region. Then texture analysis process is employed to categorize the cartilage into bright tissue and homogeneous tissue. In this process the edge of the cartilage region is detected by eliminating the soft tissues. A Bayesian decision criterion separates the cartilage region and synovial fluid automatically. Then the volume of the cartilage region and variations in the volume are detected. The authors assessed the proposed technique by comparing with the semi-automatic segmentation algorithm. They found DSC values of 0.85, 0.84 and 0.84 for the femoral, global, and tibial cartilage region, correspondingly.

Dodin et al. [6] presented a completely automatic segmentation process of the human knee by with the ray casting process. In this method, the MR image is disintegrated into several surface layers in order to find out the bone edges and the ultimate segmentation result is obtained by combining the partial segmentation objects

Ghosh et al. [7] presented the watershed-based algorithm which is begun by arranging the pixels as an array based on the value of intensity and then a threshold pixel value is fixed. In the next step, the regions with larger perimeter and the smaller cluster label are chosen to discover the cartilage region.

Kauffmann et al. [8] presented a local coordinate system (LCS) has to segment the femoral and tibial cartilage regions, which is based on a 2-D active contour algorithm. This work offered a uniform illustration of cartilage dimensions. Cartilage regions were segmented in the 3D-MRI scan and transfigured into offset maps with gaps obtained from inter - slice distance. The offset maps were expressed by the LCS. The gaps were filled with the help of a bi-cubic interpolation process.

Tang et al. [9] proposed a diffusion Snake segmentation technique is proposed and applied to synthetic and real scan images of knee cartilage region. The Diffusion Snake algorithm involves two processes, namely training stage and segmentation stage. In the training process, a collection of images is selected to apply in the training phase of the system with the data regarding the shape and shape differences. This process contains manual land-marking having the same number of uniformly-spaced landmarks employed for every dataset.

Du et al. [10] presented a cartilage segmentation process based on 3-D smoothing B-Spline active surface (SBAS). In this method, for every MR image same kind of snake is allotted initially with respect to the shape and location of the segmentation object. Snake process is governed with the help of an adaptive external forces that include the connection between the external force range and evolution process.

Tran et al. [11] a fast global minimization snake model is presented. This method employs the Chan–Vese (C-V) model and the investigation of the global diminution of standard geometric active contour (GAC) is deliberated. The conventional snake model depends on the image gradient whereas this model depends on the homogeneous regions. This method speeds up the convergence of the segmentation process.

Williams et al. [12] extended the Statistical Shape Models (SSMs) and Active Appearance Models (AAMs) are invented which contain the information of the dimension and the appearance of an object. These data are captured as a group of sample images about every corresponding point. For the automatic knee segmentation, the AAM employs the training dataset to discover the association among perturbations of the factors.

Yin et al. [13] proposed LOGISMOS (Layered Optimal Graph Image Segmentation of Multiple Objects and Surfaces) to simultaneously segment the multiple interacting surfaces.

Liukkonen et al. [14] a semi-automatic segmentation method based on radial intensity profiles to generate 3D geometries of knee joint cartilage which were then used in computational biomechanical models of the knee joint. The semi-automatic segmentation and 3D geometry construction of one

knee joint (menisci, femoral and tibial cartilages) was approximately two times faster than with manual segmentation.

Raj et al. [15] presented a knee cartilage segmentation algorithm from a high-resolution MR volume using a novel 3D-fully convolutional neural network (CNN) called ‘µ-net’ coupled with a multi class loss function.

Ababneh et a. [16] presented a fully automatic segmentation of knee bone from MRI. The authors employed a content-based image block classification method and graph-cut method. The bone detection rate and the accuracy were 99% and 95%. This method did not work well in segmenting the cartilage region.

Shan et al. [17] atlas-based cartilage segmentation technique is presented and the authors used a probabilistic classifier to generate atlas images. In this work, the femoral and tibial cartilage regions are segmented. But the mean dice similarity coefficients for femoral and tibial cartilage regions are less compared with the other works.

3.OBJECTIVES OF THE WORK

The main objectives of this research work are

- To develop a suitable pre-processing technique for MR image denoising.
- To design and develop Douglas-Rachford Splitting Based Algorithm system to segment bones from MR Images.
- To design and develop Eagle Algorithm to segment bones from MR Images.
- To perform Volumetric Assessment of Articular Cartilage.

4.RESEARCH PROBLEM

The majority of contemporary soft computing and related fields research is focused on recognizing Osteoarthritis and lesion locations in different sequences of knee MR images, which aids radiation and medical research greatly. The image segmentation procedure has greatly aided in the identification of knee bone areas in medical MR pictures.

Complex tissue architecture and aberrant locations can be easily identified using MRI scanners. Identifying the aberrant areas of the human operator can be difficult in some important scenarios, and it takes a lot of expertise and experience to do so. By

completely separating the picture, image segmentation allows a user to fully grasp the item by providing meaningful and separate sections.

The importance of image segmentation is that it processes an input image in less time and delivers exact image information. The limitations listed above can be addressed using the unique combinational architecture proposed in this research paper. The overall goal of this study is to use approximation methods to identify osteoarthritis and lesion locations in different sequences of MR images.

5.APPROACH

Preprocessing involves the denoising and assessment enhancement of MR pics this is of earlier necessity to obtain accurate cartilage segmentation. MR pictures are laid low with distinctive kinds of noise and the low comparison many of the adjoining tissues makes it hard to correctly section cartilage. In these studies, an assessment enhancement method is proposed that complements the assessment between adjacent tissues by means of increasing the photo gradient importance using the nearby grey stage S-curve transformation technique. Even after comparison enhancement improvement is challenging to section articular cartilage from MR images considering cartilage is a skinny soft tissue shape, sharing comparable intensity values with the adjoining smooth tissues like synovial fluid and has distinct shapes in distinctive slices. In all of the demanding situations worried in automatic segmentation of cartilage are mentioned, to reduce the efforts needed and to conquer the challenges confronted in the course of cartilage segmentation, a subchondral segmentation technique is proposed that localizes the cartilage in flip, helps the automatic cartilage segmentation. Right here, cartilage place is segmented by using applying multi thresholding set of rules (Otsu Method), accompanied via curvature estimation that results in separation of cartilage from the synovial fluid. The overall performance of the automated segmentation algorithm is measured by means of evaluating the obtained consequences with the manually segmented cartilage and reading the sensitivity and specificity of the proposed technique. Researchers have applied Marching dice set of rules to extract the vertices and faces from segmented slices followed by way of the rendering and visualization of three-D Articular Cartilage fashions. these 3D models are then used to compute extent of complete articular cartilage. for the reason that, the extracted iso-surfaces represent closed surfaces; the divergence theorem is used to calculate the whole quantity of AC. furthermore,

thickness of AC is calculated from the evolved 3-D models via everyday projections from one surface to another. In precise, the principal contributions of this thesis are the development of methodologies that can enhance the contrast of MR pix, mechanically segment the subchondral bones and articular cartilage from knee MR pictures observed by using the three-D visualization. The proposed techniques build a framework for automatic strategies that reduces time and efforts in quantifying morphological and physiological functions of AC.

6.CONTRIBUTIONS

The major contribution of this thesis is the implementation of an automatic segmentation and several splitting techniques to aid in the in-depth examination of diseased parts. The results clearly show that multi stochastic methodology has higher better accuracy and PSNR value with less SNR and MSE for human MR knee bone images. The approaches suggested in this research can provide a preliminary drawing for radiotherapeutic operations or image-guided surgery. Implementation of a multi stochastic objective based on random search and the comparison with existing algorithms is done. We make a conclusive statement that the proposed algorithm has better Comparison Ratio and PSNR value with reduced elapsed time.

7. ORGANIZATION OF THE THESIS

The research work is organized into Four chapters and are as follows:

CHAPTER 1

This chapter explains how to detect Osteoarthritis (OA) in the knee bone area at an early stage. Furthermore, the study effort has offered unique approaches for recognizing Osteoarthritis and segmenting the femur, tibia and cartilage of knee MR slice images, as well as the thesis structure. New medical imaging is being used to human-eye difficult injury such as osteoarthritis to provide more accurate diagnosis and more personalized care. Magnetic resonance imaging (MRI) scans are used for a variety of things, including osteoarthritis and measuring bone, cartilage, menisci. However, MRI scans have proven difficult to use for quantitative measurements of these regions, until now. In order to fully segment knee joint, cartilage images from an MRI scan, a high accuracy automatic segmentation is needed. The proximal splitting technique can handle this atomically and accurately. A recent paper detailing

the Douglas-Rachford splitting algorithm analyzed knee structures and separated cartilage. Finally, the 3-D quantization of the cartilage region is done which takes measurements to find out the growth of OA and the effects of drugs on OA.

CHAPTER 2

Some researchers used various methods to analyze problematic parts of MR Knee images, as discussed in this chapter as Literature Review. In addition, the thesis's purpose and motivation are stated in this chapter. Doctors agree that in today's living world of arthritis and aging, Osteoarthritis (OA) is the leading condition found in the knee region. Joint pain may often be due to ageing and malformed joints, but it can also be the result of continuous repetitive stress. Magnetic Resonance Imaging (MRI) has been used extensively in the medical field to detect specific issues, such MRI uncovering bone structure degradation and acting as a classification tool. Though it outlines the details about the bones, it lacks in showing faults of bones clearly due to many unfavorable conditions like fault segmentation, broken pixels or other natural faults including shaking when clicking image. Besides, manual calculations have some unexceptional errors with partial accuracy. Automated segmentation will be implemented for obtaining perfect accuracy and bone segmentation. Traditionally, content needs to be manually segmented when analyzing video. We proposed eagle algorithm to provide an improved accuracy as a machine learning model. Eagle Algorithm (EA) for the effective segmentation process of knee image is reported in our work. EA improves on the correctness and contrast in the results. Pre-processed images are usually binary with heavy noise. This can reduce this by using AF. Noise is reduced by using Anisotropic Filter (AF). Brightness of the image is controlled and stabilized through Contrast Enhancement Method (CHE). Recent developments in segmentation techniques have led to a significant reduction in time consumed by post processes. A new algorithm to fix cartilage in a clearer way has been devised by a group of researchers. They use MATLAB simulations to analyze the performance. The thickness, mean, and standard deviation all show that the proposed method has generated better results than traditional methods.

CHAPTER 3

The medical pictures acquired from private scan center; the MRI knee bone dataset were briefly explained in this chapter. In this chapter, the authors also

cover quantitative parameter analysis. A model that predicts pain progression in subjects with or at risk of knee osteoarthritis (OA) was developed by using game model and machine learning. Above average accuracy in predictability was achieved by deep-learning with a convolutional neural network. The Osteoarthritis Initiative is a study that's followed up with new results every few years. The incidence and progression cohorts of 8,000 subjects were evaluated to find out what the effects of Knee Osteoarthritis is on people. Network-based knee pain progression for knee osteoarthritis is successfully distinguished in a subset of patients by looking at empirical features. The 50,000 knees without and with pain progression were initially stratified into two sets: training (5000 knees with a mean age of 61.0 years and 60% female) and hold-out testing (1000 knees with a mean age of 65.8 years and 60% female). The performance of the model was evaluated using Area under the curve (AUC) analysis with a hold-out testing dataset.

CHAPTER 4

The role of splitting algorithm and Douglas Rach ford algorithm for segmenting knee bone MR images is covered in this chapter by the authors. The suggested Douglas Rach ford splitting algorithm effectively enhances the knee bone cartilage region of the medical picture.

CHAPTER 5

The Eagle algorithm and multi stochastic approaches for segmenting knee bone MR Images are explained in this chapter. The Eagle algorithm and multi stochastic approach detects various knee bone parts on distinct axes of knee bone MR images.

CHAPTER 6

This chapter discusses how to improve knee MR images by combining automated levy walk and intensive chasing method. The Contrast Enhancement method (CEM) approach is used to identify cartilage region and thickness of knee cartilage in knee bone MR images.

CHAPTER 7

This chapter studies into the assessment of Hybrid median filter (HMF), proximal splitting, multi stochastic optimization and intensive chase method and Eagle algorithm based on segmenting knee bone MR images.

CHAPTER 8

This chapter describes the conclusion of the research. Furthermore, this chapter is where the contributions are put together. Finally, the authors discussed how this study effort may be used to improve parameter fine-tuning in the future.

7. OVERVIEW OF THE RESULTS

Figure 1 Images showing femoral cartilage region, tibial cartilage region and patellar cartilage region of input set 1

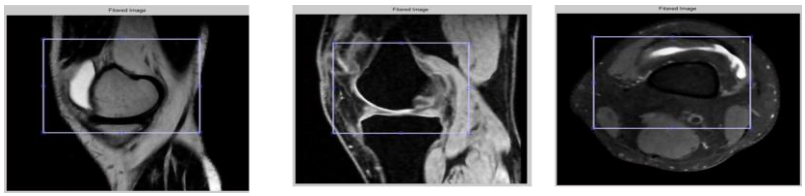


Figure 2 ROI selected of femoral cartilage region, tibial cartilage region and patellar cartilage region in input set 1

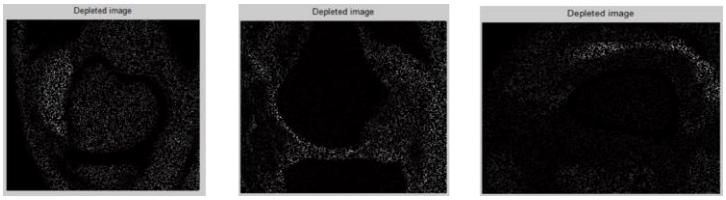


Figure 3 Depleted images (with noise) of femoral cartilage region, tibial cartilage region and patellar cartilage region in input set 1

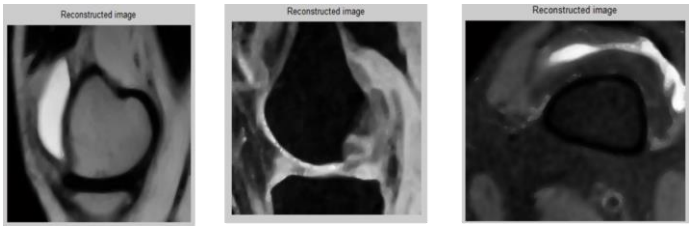


Figure 4 Reconstructed image (noise removed) of femoral cartilage region, tibial cartilage region and patellar cartilage region in input set 1

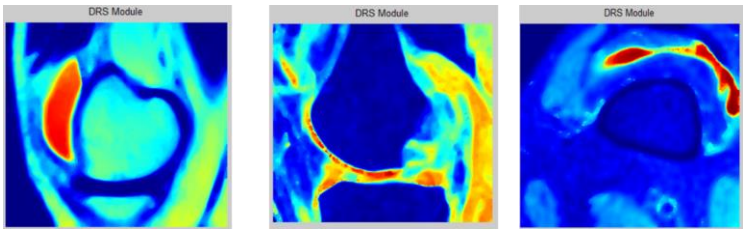


Figure 5 Proximal splitting segmented output of femoral cartilage region, tibial cartilage region and patellar cartilage region in input set 1

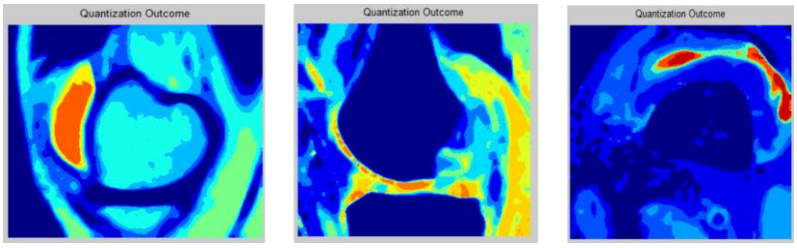
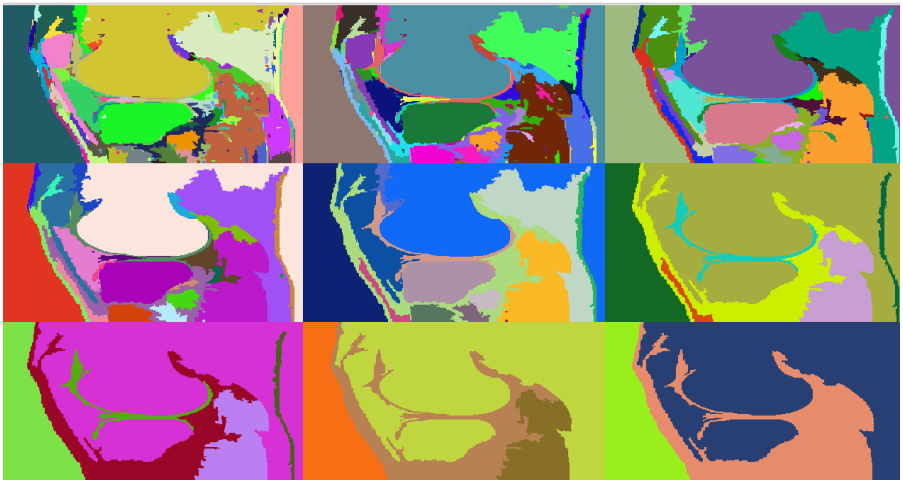
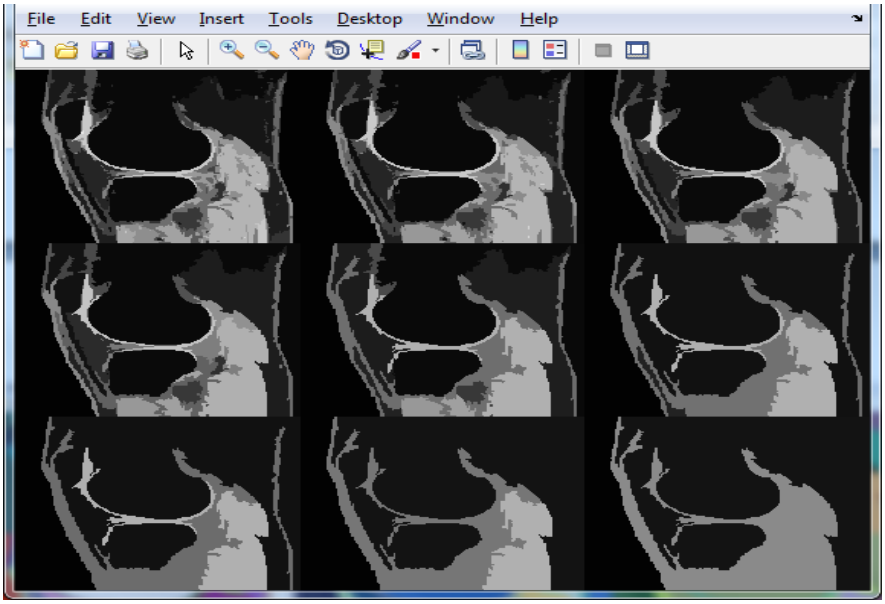


Figure 6 Quantization output image of femoral cartilage region, tibial cartilage region and patellar cartilage region in input set 1

(a)



(b)



(c)

Figure 7 Sample result from contrast enhancement method and eagle algorithm . (a) Input images (b) output obtained from eagle algorithm (c) output obtained from eagle algorithm

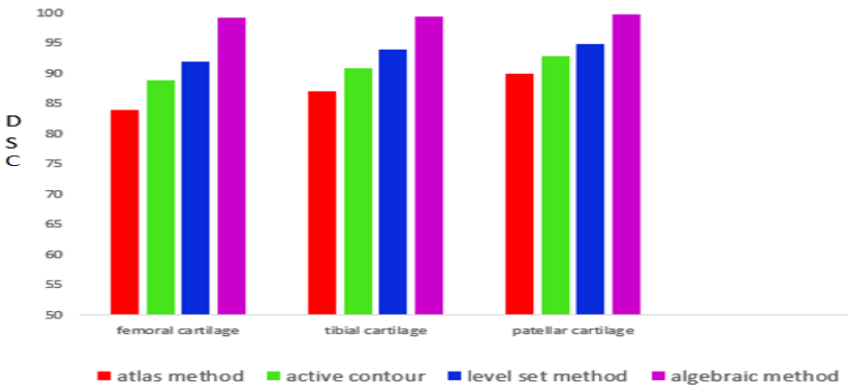


Figure 8 Overall Comparison of DSC parameters in knee bone using Douglas Rach ford splitting algorithm

Table 1 Comparison of DSC parameter

Method	**Segmented Tissue**	**DSC**				**Mean Value**
		I1	I2	I3	I4	
Atlas Based Methods	Femoral Cartilage	0.88	0.87	0.89	0.87	0.8775
	Tibial Cartilage	0.84	0.81	0.84	0.82	0.8275
	Patellar Cartilage	0.83	0.85	0.86	0.83	0.8425
Active Contour	Femoral Cartilage	0.80	0.83	0.82	0.81	0.8175
	Tibial Cartilage	0.813	0.83	0.85	0.84	0.83325
	Patellar Cartilage	0.733	0.81	0.89	0.75	0.77325
Level Set Method	Femoral Cartilage	0.871	0.87	0.85	0.85	0.86025
	Tibial Cartilage	0.848	0.85	0.81	0.83	0.8345
	Patellar Cartilage	0.817	0.85	0.83	0.84	0.83425
Proposed Algebric Method	Femoral Cartilage	0.9509	0.9874	0.9898	0.9883	0.9791
	Tibial Cartilage	0.9712	0.9745	0.9741	0.9931	0.978225
	Patellar Cartilage	0.9218	0.9057	0.9540	0.9015	0.92075

Table 2 Volume measurement

Segmented tissue	**Thickness**			
	Input set 1	**Input set I2**	**Input set 3**	**Input set 4**
Femoral cartilage	0.1937	0.2185	0.3038	0.1937
Tibial cartilage	0.1908	0.2395	0.3024	0.1908
Patellar cartilage	0.2341	0.2857	0.2786	0.2341

Figure 1 shows the input image utilized in the research and Figure 2 depicts the region of interest for OA detection. Figure 3 shows the depleted image with noise of the femoral, tibial and patellar cartilage region and the same was reconstructed and shown in Figure 4. Initial segmentation was done using the proximal splitting algorithm and the result of the same was shown in Figure 5. The quantized result for volume measurement is shown in Figure 6. Figure 7 (a) shows the input images and Figure 7 (b) and Figure 7 (c) shows the sample result from contrast enhancement method and eagle algorithm. Figure 8 depicts the overall Comparison of DSC parameters in knee bone using Douglas Rach ford splitting algorithm. Table 1 and Table 2 provides the comparative analysis of DSC parameter and Volume measurement.

8. CONCLUSION

Since the manually segmentation techniques contain some hitches of inter user and intra user reproducibility of computations, in this research, we presented a fully automatic segmentation technique to segment the human knee bone from the MR scan images and this method considers the characteristics of the development which happens in the tissue during osteoarthritis. The proposed method is evaluated by comparing the developed proximal splitting-based segmentation method with the other conventional segmentation methods and the performance measures are compared. Though our method lags comparing with the active contour technique, the drawbacks of active contour method like large computation time, computational complexity and initial contour selection are overcome in this method. In the proposed technique, the values of parameters such as DSC, specificity and sensitivity are 97.12%, 98.28% and 99.72%.

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